

decade intervening between two maxima. In 1870-71, and again in 1890-91, the evidences of unusual activity in the belt remained visible for a long time, probably a year or more; but the recorded observations neither enable us to determine the length of the whole period or the precise dates of its earliest cyclical presentations. The evidence roughly indicates a period of 10.2 years, but it remains for future observation to finally affirm the fact of its occurrence and to accurately define the interval. Even if additional data fail to corroborate the views here formulated we shall at least have advanced a step nearer the truth, and shall be the more ready to relinquish our vague ideas as to distinctly periodical changes on *Jupiter*. For my own part I shall be willing to admit that many of his atmospheric features, though undoubtedly far more durable than our own, yet display many similar vagaries. I do not, however, anticipate that future experience will furnish a negative, but that when the planet is examined, either at a late period in the opposition of 1900 or at the earliest time in that of 1901, the north temperate belt will exhibit a similar disturbance to that which has marked it in the closing year of each of the last five decades. It is perhaps unfortunate that *Jupiter* will be in conjunction with the Sun in 1900 December, and that quite possibly the expected phenomena may in a great measure escape record. If *Jupiter* had been in conjunction in 1860 March and 1880 November the remarkable transformations of the belt which occurred at those epochs would never have become matters of history. It is to be expected, however, that, in the event of a well defined recurrence, the evidences of it will be favourably visible in the spring and summer of 1901. The duration seems to be very variable, for its chief intensity lasted about two months in 1860, three months in 1880, and certainly more than twelve months at its last apparition in 1890-91.

Bristol:
1898 November 30.

The Extra-equatorial Currents of Jupiter during the Apparition of 1897-98. By Rev. T. E. R. Phillips.

(Communicated by W. F. Denning.)

The following is a short discussion of the chief spots and currents visible on *Jupiter* during the last apparition outside the equatorial regions, omitting the three dark spots on the N. tropical zone which have been already discussed by Mr. Denning in the *Observatory* (May and September numbers).

Including the red spot, six distinct currents are denoted below, and it is noteworthy that only in the cases of the north north temperate belt, and, perhaps, a belt still further north

(not included in this discussion), was the rotation period equal in length to that of the red spot.

As has been shown by Mr. A. Stanley Williams in his paper "On the Drift of the Surface Material of *Jupiter* in different Latitudes," *Monthly Notices*, R.A.S., vol. lvi. No. 3), the various Jovian currents are by no means symmetrically arranged. In particular, there is a striking difference in the sequence of currents in the N. and S. hemispheres. The N. hemisphere contains in close contiguity both the slowest and swiftest Jovian currents known, though the latter was not apparent last apparition owing to the absence of spots and other observable markings in that latitude. The slowest current detected on the disc was in latitude about $+33^\circ$, its rotation period being $10^s.4$ longer than the period of System II. (Mr. Crommelin's *Ephemeris for Physical Observations of Jupiter*), and $25^s.7$ longer than that of the N. tropical zone, which Mr. Denning found to be $9^h 55^m 26^s.3$. On the other hand, in the S. hemisphere, with the exception of the red spot, the periods of the various currents seem to diminish gradually from the S. equatorial belt towards the pole, though a determination of the velocity of the surface material further S. than latitude -40° was not made last apparition through the absence of markings sufficiently definite and distinct to enable their transit times to be taken.

In this investigation of the extra-equatorial currents valuable assistance has been received from Mr. W. F. Denning, F.R.A.S., Mr. A. S. Williams, F.R.A.S., and Mr. J. Gledhill, F.R.A.S.

The following tables for the most part explain themselves. After the title of each current will be found a statement of the *estimated* latitude, and the mean value of its rotation period (R). Observations of the individual spots follow headed by their adopted periods. The third column (O—C) contains the residuals or differences between the observed and computed positions according to the adopted period, and thus shows at a glance how far that period satisfies the series of observations.

The following is the explanation of Mr. Williams's system of abbreviations employed in the column for "remarks" :—

S = small.	vB = very bright.
vS = very small.	mB = moderately bright.
eS = exceedingly small.	F = faint.
D = dark.	vF = very faint.
B = Bright.	eF = exceedingly faint.
eB = exceedingly bright.	eeF = most exceedingly faint.

Dark Streaks on North North Temperate Belt.

Latitude about $+33^\circ$. Mean R = $9^h 55^m 52^s.0$.

Two long dark spots or streaks were observed on this belt, both of which exhibited periods considerably longer than that of System II.

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Streak I. $R=9^h 55^m 53^s.4$.

Accurate observations of this streak were somewhat difficult to obtain, especially towards the close of the apparition, when it seemed to lose much of its definiteness of outline, and to become somewhat vague and diffuse. It was considerably longer and more diffused than streak II. in this latitude. The periods of the *preceding end* and *centre* of this streak were computed separately, but being practically identical, the period here adopted is the mean of the two results. The difference of longitude between the p. end and centre is allowed for in the following table :—

Date.	Longitude (System II.).	O—C.	Observer.	Remarks.
1898.				
April 15	55 ^c .6	—2 ^o .8	Phillips	Centre.
25	53.7	+4.3	„	Prec. End.
27	46.9	—3.1	„	„
30	52.0	+1.1	„	„
30	65.8	+2.8	Williams	Centre.
May 4	49.1	—3.1	Phillips	Prec. End.
12	57.0	+2.5	Denning	„
31	60.6	0.0	Phillips	„
31	72.7	+0.1	„	Centre.

Streak II. $R=9^h 55^m 50^s.7$.

March 21	265.5	—1.2	Phillips.	
28	267.8	—0.6	„	
April 5	272	+1.7	Nijland.	
7	267.5	—3.4	Denning.	
12	277.0	+4.9	Phillips.	
17	268.8	—4.5	Denning.	
17	276.0	+2.7	Phillips	Length = 9 ^o .7
19	275.3	+1.5	Williams.	
19	274.1	+0.3	Denning.	
22	271.3	—3.2	„	
May 6	277.1	—0.9	„	
6	279.6	+1.6	Phillips.	
16	281.6	+1.2	Denning.	
18	279.6	—1.3	„	
18	280.1	—0.8	Phillips.	
23	281.9	—1.4	„	
June 4	285.0	0.0	„	
16	288.0	0.0	Denning.	
28	291.8	+0.9	„	
July 3	294.1	+2.0	„	

Note.—There was a marked intensification or condensation of the dark material on a belt in lat. about +39°. Several transits were taken, but, owing to the increasingly ill defined character of the marking and the great

difficulties in the way of securing accurate observations, the discordances were so great that any determination of the period must necessarily be uncertain and unreliable. This object has therefore been omitted from the present discussion.

"The Red Spot."

This spot, except at its s.f. end, was again very faint and difficult. At times, when the seeing was good, the complete oval outline could be distinctly made out, but as a rule the boundary of the p. end was difficult to determine with certainty. The region n.p. and p. the spot was exceedingly brilliant, and possibly this, by an effect of irradiation, may *partly* account for the apparent displacement of the spot towards the f. end of the well-known "bay" or hollow in the S. equatorial belt in which it lies. To the writer the spot appeared to transit the c.m. about three minutes later than the centre of the "bay," and as Mr. Denning also calls attention to the displacement, and some indication of the same appearance is furnished by Mr. Gledhill's figures published in the supplementary number of the *Monthly Notices* of the R.A.S., vol. lviii. No. 9, there seems every probability that the displacement of the spot towards the f. end of the "bay" was an objective reality, though irradiation, together with the less prominent character of the p. "shoulder" compared with that following the spot, may have caused such displacement to appear somewhat exaggerated.

Throughout the apparition the red spot was in contact with the S. temp. belt.

As regards the colour of the spot the general opinion of observers seems to be that almost all trace of red had disappeared. To the writer the colour appeared distinctly grey.

During the past apparition of the planet the red spot exhibited a still further increase in the length of its rotation period. $R=9^h 55^m 42^s.1$.

Date.	Longitude (System II.).	O-C.	Observer.	Remarks.
1898. March 5	21°8	+0.2	Williams.	
15	21.2	-0.8	MacEwen.	
22	22.7	+0.5	Williams.	
22	23.6	+1.4	Denning.	
29	21.1	-1.4	Williams.	
29	23.1	+0.6	Phillips	A grey oval ring, darker sf.
31	22.4	-0.1	Williams.	
April 1	22.4	-0.2	MacEwen.	
5	23.3	+0.6	Williams.	
5	23.6	+0.9	Gledhill.	

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Date.	Longitude (System II.).	O-O.	Observer.	Remarks.
1898. April 8	22°8	0°0	Williams.	
8	23°4	+0°6	Gledhill.	
12	20°0	-3°0	Williams.	
15	21°3	-1°8	„	
15	22°6	-0°5	Denning.	
15	24°8	+1°7	Phillips.	
17	21°0	-2°1	Williams.	
17	23°6	+0°5	Denning.	
17	23°6	+0°5	Phillips	Very bright n.p
18	25°2	+2°0	Denning.	
22	24°9	+1°6	„	
22	21°4	-1°9	Williams.	
25	24°7	+1°3	Phillips.	
27	22°4	-1°1	Williams.	
27	25°1	+1°6	Phillips	Grey oval shading, gradu- ally darkening to s.f.
30	24°8	+1°2	„	
May 4	25°1	+1°4	Gledhill.	
4	25°4	+1°7	Williams.	
9	21°6	-2°3	„	
12	24°1	-0°1	Gledhill.	
14	23°8	-0°3	„	
14	24°1	0°0	Denning.	
14	25°1	+1°0	Williams.	
28	25°0	+0°4	Gledhill.	
31	24°8	+0°1	„	
June 7	25°9	+0°9	Denning.	
7	26°4	+1°4	Williams.	
7	29°4	+4°4	Phillips.	
10	23°6	-1°5	Gledhill.	
12	23°8	-1°3	„	
12	28°7	+3°6	Denning.	
14	24°3	-0°9	Gledhill.	
17	25°6	+0°3	„	
19	27°4	+2°0	Phillips.	
24	25°3	-0°3	Gledhill.	
July 11	23°8	-2°4	„	
13	24°4	-1°8	„	
13	24°6	-1°6	Denning.	
30	30°1	+3°2	„	

White Spots on South Tropical Zone.

Three spots were observed sufficiently well to enable a determination of the value of R to be made.

Latitude about -20° . Mean $R = 9^h 55^m 25^s.6$

Spot I. $R = 9^h 55^m 34^s.4$.

Date.	Longitude (System II.)	O-C.	Observer.	Remarks.
1898. April 13	$58^\circ.2$	$-1^\circ.1$	Phillips	Spot seen and drawn on March 22 connected by rift with rift in S. E. B.
13	$58^\circ.3$	$-1^\circ.0$	Williams	S, F, not well defined; irregular in shape and brightness. A narrow, bright rift ran n.f. from it through S band of S. E. B.
15	$59^\circ.8$	$+0^\circ.9$	"	vS, F, rift n.f. glimpsed.
15	$64^\circ.2$	$+5^\circ.3$	Booth.	
25	$57^\circ.4$	$0^\circ.0$	Phillips.	
30	$56^\circ.7$	$0^\circ.0$	Williams	S, F, ill defined; rift n.f. not seen.

Spot II. $R = 9^h 55^m 29^s.2$.

Date.	Longitude (System II.)	O-C.	Observer.	Remarks.
1898. March 29	$110^\circ.7$	$+1^\circ.3$	Williams	vS, vF.
April 8	$106^\circ.9$	$+0^\circ.3$	"	"
13	$104^\circ.3$	$-0^\circ.9$	"	vS, eeF, ill defined, very difficult.
18	$109^\circ.9$	$+6^\circ.1$	Phillips.	
30	$100^\circ.2$	$-0^\circ.3$	Williams	vS, F.
June 5	$90^\circ.4$	$0^\circ.0$	"	vS, vF.

Spot III. $R = 9^h 55^m 13^s.2$.

Date.	Longitude (System II.)	O-C.	Observer.	Remarks.
1898. April 16	$166^\circ.6$	$+2^\circ.5$	Williams	vS, F.
30	$152^\circ.2$	$-2^\circ.5$	"	"
May 15	$145^\circ.0$	$+0^\circ.3$	"	vS, vF.
June 3	$131^\circ.6$	$-0^\circ.4$	"	"

South Temperate Spots. (Spots on S. Temp. Belt or at its S. Edge).

Mean latitude -30° . Mean $R = 9^h 55^m 19^s.4$.

Several spots were seen in this latitude, but some of them were not observed sufficiently well to enable reliable rotation periods to be deduced. They have therefore been omitted from this discussion. In the following list Spots II. and IV. might perhaps be considered as belonging to a different current. They appeared to project into the light zone S. of the S. temp. belt,

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and to be affected somewhat by the more rapid rotation of the dark material still further S., thus forming a kind of intermediate or transitional current. As, however, they were clearly connected with the S. temp. belt they have been included under this heading.

Spot I. White. R=9^h 55^m 21^s.7.

Date.	Long. (System II.)	O-C.	Observer.	Remarks.
1898. March 29	20 ^o .1	0 ^o .0	Phillips.	
April 5	19.2	+2.3	Williams	eS, eB, well defined, slightly oval, E and W.
12	12.1	-1.6	„	vS, vB, well defined.
15	14.0	+1.7	Denning.	
15	9.2	-3.1	Williams	vS, vB, well defined.
17	8.5	-2.9	Denning.	
17	12.3	+0.9	Williams	eS, vB, well defined, slightly oval.
17	12.1	+0.7	Phillips	Very brilliant.
22	7.8	-1.3	Williams	eS, vB, well defined.
22	5.6	-3.5	Denning.	
27	4.9	-1.9	Williams	eS, vB, well defined.
May 2	4.6	+0.1	Denning.	
4	3.0	-0.6	Williams	eS, eB, very well defined, nearly round
4	6.8	+3.2	Phillips.	
14	358.1	-0.9	Denning.	
June 7	349.6	+1.6	„	

Spot II. White. R=9^h 55^m 11^s.5.

Date.	Long. (System II.)	O-C.	Observer.	Remarks.
1898. May 9	29 ^o .5	-0 ^o .5	Williams	eS, mB.
14	29.3	+2.8	„	eS, mB, well defined.
June 2	12.5	-0.4	Phillips.	
7	14.3	+4.9	Williams	eS, F.
19	0.2	-0.7	Phillips.	

Spot III. White. R=9^h 55^m 29^s.4.

Date.	Long. (System II.)	O-C.	Observer.	Remarks.
1898. March 29	110 ^o .7	0 ^o .0	Williams	vS, mB.
April 6	110.5	+1.9	Phillips.	
8	108.1	-0.1	Williams	eS, vB, nearly round.
13	105.5	-1.1	„	eS, B, well defined.
30	101.4	-0.6	„	eS, F.
June 5	92.4	+0.2	„	eS, F.

H

Spot IV. White. $R=9^h 55^m 14^s.6$.

Date.	Long. (System II.)	O-C.	Observer.	Remarks.
^{1898.} April 4	170°9	0°0	Denning.	
(13	173°4	...	Williams	vS, mB, well defined except on F side, where it expands into a broad white streak.)
(16	170°9	...	„	vS, F.)
30	153°7	-0°7	„	vS, B, well defined.
May 15	144°7	-0°3	Denning.	
15	145°9	+0°9	Williams	S, B, well defined. A large and con- spicuous object. Perhaps really compound, and formed of several small spots close together.
June 3	132°9	0°0	„	vS, B, well defined.

Note.—It is very uncertain whether the observations of April 13 and 16 relate to this spot at all. A comparison of these two observations with drawings made about this time seems to show that they do not.

Spot V. Dark. $R=9^h 55^m 18^s.5$.

Date.	Long. (System II.)	O-C.	Observer.	Remarks.
^{1897.} Dec. 30	230°1	-1°5	Phillips	Belt f. this spot broader and almost certainly double.
^{1898.} April 16	180°0	+6°1	Williams	eS, D, on S.T.B.
30	161°9	-4°4	„	eS, mD.
May 15	158°0	-0°3	„	eS, mD, elongated E. and W.
15	150°7	0°0	Denning	P. end of thickening of belt.
June 22	129°9	-0°2	„	„ „
July 2	125°1	+0°3	„	„ „

Note.—The spot observed on 1897 December 30, following which the S.T.B. became wider and apparently double, is almost certainly identical with that which during the later months of the apparition marked the commencement of the thickening of the belt referred to by Mr. Denning. The p. end of this thickening of the belt and the centre of the spot showed the same rate of rotation, their mean difference of longitude being allowed for in the above table.

Spot VI. White. $R=9^h 55^m 20^s.6$.

Date.	Long. (System II.)	O-C.	Observer.	Remarks.
^{1898.} March 21	243°5	0°0	Phillips.	
May 3	221°8	-0°7	Williams	eS, mB, on S. side of <i>double</i> S.T.B. and visible in rift also.
June 1	209°6	+1°2	„	vS, mB, ill defined.

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*Southern Spots.*Latitude about -40° . Mean $R=9^h 55^m 6^{\cdot}3$.

This region is included in Mr. A. Stanley Williams' Zone IX. ("Drift of Surface Material of *Jupiter* in different Latitudes"), and is remarkable for its rapid rotation relatively to that of the zero meridian of System II. Two definite spots were seen last apparition, and observed with sufficient frequency to enable tolerably reliable rotation periods to be computed. The considerable south latitude of the spots, however, made accurate observations of their transit times very difficult to obtain except when the seeing was good; and to this, coupled with the somewhat faint and vague character of the markings, is doubtless to be attributed some of the discordances in the following table of positions:—

Spot I. Dark Ellipse. $R=9^h 55^m 5^{\cdot}3$.

Date.	Long. (System II.)	O—O.	Observer.	Remarks.
1898. March 23	177 $^{\circ}$ 7	0 $^{\circ}$ 0	Phillips	Long dusky spot S. of S.T.B. in a well-formed bay in that belt.
April 4	163 $^{\circ}$ 7	-3 $^{\circ}$ 7	„	Spot become extended in an E. and W. direction.
16	155 $^{\circ}$ 3	-1 $^{\circ}$ 7	Denning	A short dark streak. Time very doubtful.
16	160 $^{\circ}$ 1	+3 $^{\circ}$ 1	Phillips.	
18	153 $^{\circ}$ 4	-1 $^{\circ}$ 8	Denning.	
18	160 $^{\circ}$ 1	+4 $^{\circ}$ 9	Phillips	Dusky oval spot.
19	153 $^{\circ}$ 8	-0 $^{\circ}$ 7	Denning.	
23	153 $^{\circ}$ 0	+2 $^{\circ}$ 0	„	
30	145 $^{\circ}$ 1	+0 $^{\circ}$ 2	Phillips	Moved very considerably to the W. Changed its position relatively to the bay in S.T.B.
May 12	139 $^{\circ}$ 2	+4 $^{\circ}$ 6	„	Very bad air. Ellipse not seen distinctly, only a vague ill-defined shading.
15	128 $^{\circ}$ 1	-4 $^{\circ}$ 0	Williams	Time "estimated."
June 5	115 $^{\circ}$ 0	+1 $^{\circ}$ 2	Phillips	Dark ellipse now very vague and doubtful.
10	104 $^{\circ}$ 1	-5 $^{\circ}$ 5	„	Mere suspicion of dark ellipse.
22	97 $^{\circ}$ 9	-1 $^{\circ}$ 3	Denning.	

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Spect II. Dark condensation of S.S.T.B. R=9^h 55^m 7^s.4.

Date.	Long. (System II.)	O-C.	Observer.
April 22	317.8	-2.0	Denning.
May 4	307.0	-3.1	Phillips.
6	307.4	-1.0	Denning.
6	308.6	+0.2	Phillips.
11	304.9	+0.5	"
16	295.5	-4.9	Denning.
16	300.7	+0.3	Phillips.
18	292.3	-6.4	Denning.
18	298.5	-0.2	Phillips.
28	292.1	+1.4	"
June 4	286.2	+1.2	"
11	279.4	+0.1	"
16	272.9	-2.4	"
28	259.8	-5.8	Denning.
July 5	264.9	+5.0	"

Summary of Results.

Current.	Approx. Lat.	No. of Spots observed.	Rotation Period. h m s
1. N.N. Temp. Belt	+33 ^o	2	9 55 52.0
2. *N. Trop. Zone	+15	3	9 55 26.3
3. S. Trop. Zone	-20	3	9 55 25.6
4. "Red Spot"	-21	1	9 55 42.1
5. S. Temp. Belt	-30	6	9 55 19.4
6. Southern Spots	-40	2	9 55 6.3

Observations of Planet (433) (1898 DQ) made at the Royal Observatory, Greenwich, with the 30-inch Reflector of the Thompson Equatorial.

(Communicated by the Astronomer Royal.)

Photographs of Planet DQ were obtained with the 30-inch reflector of the Thompson Equatorial on 1898 December 7 with exposures of 3^m, 5^m, and 7^m, and on December 9 with exposures of 10^m, 6^m, 5^m, and 4^m. The 7^m and 5^m exposures on December 7 and the 6^m and 5^m exposures on December 9 of the planet and of eight or ten reference stars have been measured in the duplex micrometer, four measures being made of each image of the planet and two of each of the star-images, by two observers.

The right ascensions and declinations of the reference stars have been derived from the Karlsruhe Observations 1883-91, the Radcliffe Catalogue, 1890, and Schjellerup's Catalogue, 1865.

* Discussed by Mr. Denning in the *Observatory* for May and September.